March 2007

Case Studies

Life cycle costing (LCC) as a contribution to sustainable construction: a common methodology

Case Studies – Annex to Guidance Document

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Contents

1 Introduction to case studies

The case studies have been assembled in order to test and validate the feasibility of the proposed methodology. The six case studies presented here are a representative sample from different Member States and include five representing public procurement and one representing a private project.

The aim of applying the proposed methodology to the case studies was to:
- outline any special requirements to adapt the methodology according to the type of project and/or construction assets concerned
- outline any special requirements to adapt the methodology according to different national contexts
- underpin the selected examples in the 'Guidance on the use of the methodology'.

The following case studies were submitted for "testing" of the methodology:
- Project **INSPIRE for a FM company in the UK** comprising 2 buildings, one new build and one refurbishment. This case study represents application of LCC in private sector and underpins the example in the Guidance for selected stages of the facility's life cycle.
- Project **Digi-house (Digitalo)** comprising the development of office accommodation in **Otaniemi, Finland** for a public client by VTT (Technical Research Centre of Finland). This case study represents the use of LCC for all stages of the facility's life cycle with strong focus on sustainable performance.
- Project for the college **Maximilien Perret of Alfortville, France** comprising a large, multi-functional building to support many forms of adult and professional education. The building represents modern, cutting-edge design and the case study represents the application of LCC to selected stages of the facility's life cycle. The LCC exercise was commissioned by a public sector client with a focus on the application of LCC to challenging designs and was carried out by the CSTB (Centre Scientifique et Technique du Bâtiment).
- Project for office accommodation commissioned by a public client in the **Netherlands** and designed and costed by the Ministry for VROM (Housing, land-use planning and environmental management). This case study represents the use of LCC for a selected 15 year stage of the overall life cycle. The project represents the application of LCC to a project with extensive site restrictions.
- Project of hospital accommodation in **Porsgrunn, Norway** carried out for a public client and assessed by Statsbygg (The Directorate of Public Construction and Property). This project reflects example from the Guidance Note which underpins the use of LCC initially for strategic assessment of the asset and then for more detailed assessments and calculations.
- Use of LCC to select systems to ensure the optimal environmental performance in the **Museum of World Culture in Gothenburg, Sweden**. This project corresponds to the example from the Guidance which describes calculating LCC for selected systems and components.

2 Application of LCC methodology to a project for two facilities (new - build and refurbishment) for major FM provider in the UK

Project description

Project title - INSPIRE

Category – New laboratory building and refurbished office accommodation for private sector.

General project information – Serco Group plc ("Serco") has been selected as preferred bidder by the Defence Science and Technology Laboratory ("Dstl") for a 15 year strategic partnership contract called 'Project INSPIRE'. Serco has selected Building Design Partnership (BDP) as its design leader and Sir Robert McAlpine Limited as its construction partner.

The contract aimed at providing and support new and refurbished laboratory and office accommodation. As a strategic partner and prime contractor, Serco is responsible for providing comprehensive facilities management services across Dstl's estate for 15 years from August 2006. In the first 2 years, Serco is also managing the design and build of new facilities and refurbishment of others and is migrating approximately 1500 Dstl staff to them. The innovative new facilities and supporting services range from laboratory set-up to travel management services.

Year of construction - 2006-2008 (under construction)

Gross internal floor area (GIFA) – 20,390 m^2

Aims and objectives of LCC analysis

A model has been prepared in order to illustrate likely future expenditure required on both buildings of the project (new build and a refurbishment).

A rigorous methodology has been adopted in the development of replacement cycles, and the model has been presented as a 'first cut', that is, without extensive smoothing of the expenditure profile.

Three models were produced for each site; the first, the 'likely' scenario plus two variants reflecting favourable and unfavourable scenarios below and above the 'likely', referred to as the 'best' and 'worst' case scenarios.

The models represented results from the research of data and cost options extracted from a variety of databases. They included the upper, lower and middle values the range of expected outcomes.

LCC process

Objective

The savings from comparing options were mainly related to the capital costs and were assessed at the initial design and design refinement stages by the design team and the client without taking into account the LCC. Therefore when the LCC was carried out it was mainly for budgeting purposes with input of the "best", "least favourable" and then calculating the "middle" estimates.

The model was prepared at a certain point in time and thus could not be assumed to be a 'catch-all' solution. The model will require updating in the light of any future design development and during procurement of the Construction/Transition stage.

Preliminary identification of parameters and analysis requirements

The scope of the analysis involved the total asset and refinements and upgrades were made throughout the design. The level of detail was at system/component level and was pre-determined at the design stage. The LCC was carried out for essentially one set of recommended choices of components.

The Appraisal Period instructed for the Model was 50 years. This reflected the design life of the buildings as advised by BDP (design). Whilst the term of the proposed contract was 15 years, the 50 year model was presented in order to illustrate a consistent approach to the whole life of the facilities and to demonstrate that there was no undue expenditure following the hand-back to Dstl. The method of economic evaluation required by the client was NPV only.

At the design stage many trade-offs were made to select more environmental solutions at the systemic level. Environmental considerations were high on the client's agenda and a BREEAM (UK BRE Environmental Assessment Method) rating of "excellent" was a target for these buildings.

Risk assessment was carried out for the performance of the facilities rather than the LCC and concentrated on formal risk assessment. The analysis of three LCC options (best, worst and the middle values of costs and selected financial parameters) were considered to be sufficient to provide robust sensitivity information.

Confirmation of project and facility requirements

The facility's requirements were selected among the design team to enable the combination of parameters, such as NPV, environmental performance, budgetary restrictions and suitability to be achieved within the project programme. The assessment was not carried out using the LCC analysis or models.

The main environmental options tested using LCC were selected as traditional air conditioning systems versus use of chilled beams. The identification of the two systems was carried out by environmental specialists.

With regard to project requirements, there was no fixed budget as such but selected options were costed and decisions were made based on the relative impacts, costs implications and performance at the design stages. The site constraints and project constraints were agreed and acted upon between the client and the design team. The same applies to the quality requirements.

Assembly of cost and performance data

All costs were itemised and costed using the BCIS classification system. The cost data was derived from BCIS databases (UK's Building Cost Information Service), Davis Langdon (cost consultants) internal databases, contractor's databases and other available published data. The main exercise was carried out for two options of HVAC solutions. At the time of calculations, the capital costs that fed into the Model were in cost plan form only (contractor's MPTC figures), thus with only generic information on the works being undertaken, assumptions were made as to the quality of the materials and workmanship.

Values of financial parameters were identified as follows: discount rate of 3% (real - as advised by Treasury Green Book) and no inflation. This allowed for the fact that the opportunity cost of money meant that monies spent in the future were worth less in present day terms.

The model was indexed to reflect any inflation between the date of the costs and the start date of the model. The source prices included an allowance for indexation up to and through the Construction period. To allow to present 2005 prices for the Maintenance and Asset Replacement cost streams, a deflator has been used for the annual costs, which was published by the BCIS and typically used for these types of calculations.

Replacement timings for the assets were assessed using a combination of Davis Langdon's own database and published information on the likely life expectancy of various assets. Refinement of this was made by adjustment of the percentage of the capital cost which was allowed at each replacement cycle. For instance, on average, windows may be expected to last around 20 – 35 years, dependent on quality of materials and workmanship. However, the likelihood was that many will last considerably longer, whilst some may fail early. Two mechanisms were used to account for this. Firstly, a percentage of the capital cost was allowed at the earlier published life expectancy, and secondly, the expenditure was spread over more than one year, allowing some money to be drawn down early, should it be necessary.

The desired redecoration cycle for the facilities was carefully considered. Another asset that required consideration was loose furniture, as this could add considerably to the cost of a facility over time. The 'norms' used on other office accommodation projects at Davis Langdon were used.

Different types of obsolescence were of importance in assessing asset lives. For instance, whilst office fit-out components might not become physically obsolete for 20 or more years, if carefully maintained, it was commonly understood that they may become functionally, or aesthetically obsolete within a much shorter timescale. Thus a realistic assessment of life cycle costs had to take into account these aspects in addition to the physical durability.

Cost add-ons which were listed included certain costs associated with the replacement work, all necessary scaffolding, temporary access and temporary works, as well as removal of the components to be replaced and testing/commissioning of plant and equipment. Exclusions which were listed broadly included the following: contingencies, VAT and other relevant financing charges and rates, certain management fees, business interruption costs/unavailability, backlog charges , hard and soft FM services, relocations and insurances.

Approach to sensitivity comprised identification of maximum and minimum values published or used as common practice and c alculating "the middle" value of selected parameters, which were: selected cost data and selected financial parameters.

An external risk register was produced by the design team; however it was not directly linked to the LCC calculations.

LCC analysis and results

All the financial parameters were applied uniformly to all cost groups. No allowance has been made within the Model for any financial advantages that may be gained via Capital Allowances, etc.

All the values were input in the IT tool (internally developed Davis Langdon tool) for calculating the financial performance over the selected life cycle period.

Auxiliary analyses (risk & sensitivity) – optional

No formal quantitative risk analysis was carried out as it was difficult to assess the probability distributions of uncertain parameters.

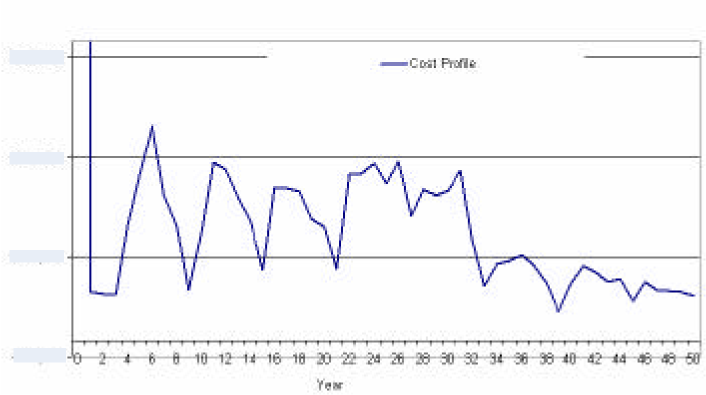
For each building, three alternative models were provided giving a 'likely' scenario plus two variants reflecting favourable (best) and unfavourable (worst) scenarios below and above the 'likely' one.

Interpretation and reporting

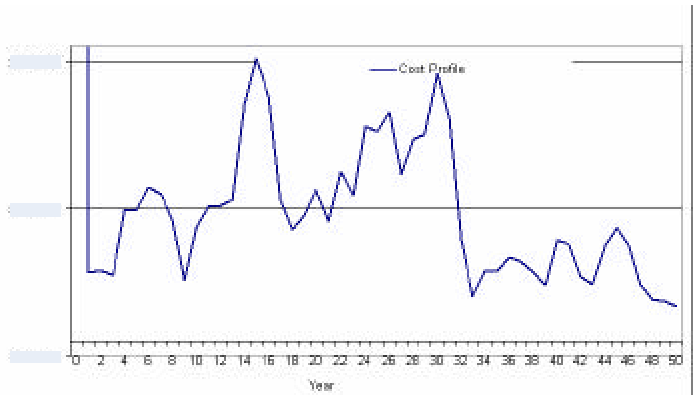
Preliminary results included the outputs from the Excel based LCC tool, providing the following information: tables of costs, parameters of the analysis, annual expenditure and detailed cost profile.

The formal report for the client was structured according to the headings in ISO 15686 – Part 5.

Results – Refurbishment



Results – New Build



Results (continued)

The average annual spend per metre square of Gross Internal Floor Area (GIFA) was slightly lower for a refurbished building than for the new one. This might be partly due to the fact that certain building elements, such as internal doors and partitions, to be kept during the refurbishment had not been quantifiable at this stage, and thus whilst an assessment of their impact had been made, this may not be as accurate as in the situation where a full cost plan for a new build is available.

The lower overall figures for a 13 year model (a quarter of the 50 year "life"), as opposed to a 50 year model were a natural consequence of the fact that the majority of building components, and particularly the more expensive items of plant, would have an expected life greater than 13 years.

Overall, the costs, when adjusted to mitigate the various unusual aspects of the project fall broadly in line with industry benchmarks for life cycle costing exercises.

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Conclusions and benefits

The main benefits were twofold, firstly the FM provider was able to show to their client that they are planning to invest during the O&M stages and they are planning the relevant expenditure and secondly Serco gained a practical insight into not only future costs but also their timings so they could plan their financial strategy to suit.

Whatever figure was budgeted for, it was underpinned by a robust management plan which was then implemented and will be regularly reviewed throughout the life of the building.

The other benefits included:

- Setting out a clear strategic approach to asset management.
- Benefiting from putting in place an effective management regime
- Ability to communicate the actuality of which/when assets will be replaced during the term
- Development of a clear mechanism for identifying the circumstances when an asset should be replaced, or when its life can be 'sweated' further
- Informed participation of all parties concerned

3 Digi-house (Digitalo) – office building in Otaniemi for Senate Properties in Finland

Project description

Project title Digi-house (Digitalo)

Category – New-build office building

General project information – VTT Digi-house has space for 270 employees. The project was implemented using the project/construction management method. The work was divided into several contracts, deliveries and procurements. The target was to design an office building, where the versatility of the office space and life cycle and environment issues were taken into account.

Client: Senate Properties

User: State Technical Research Centre (VTT)

The design was carried out by using integrated CAD. The steel structures of the hanging floors in the central hall were designed three-dimensionally using the Tekla Structures software.

Year of construction: January 2003 - commencement of design, January 2004 - commencement of construction, September 2005 - construction completed

Gross internal floor area (GIFA) – 8,800 m^2

Aims and objectives of LCC analysis

The main objective was to achieve an office building of superior functionality and quality, with improved infrastructure, representing added value for the customers and designed with application of proven solutions for improving environmental performance.

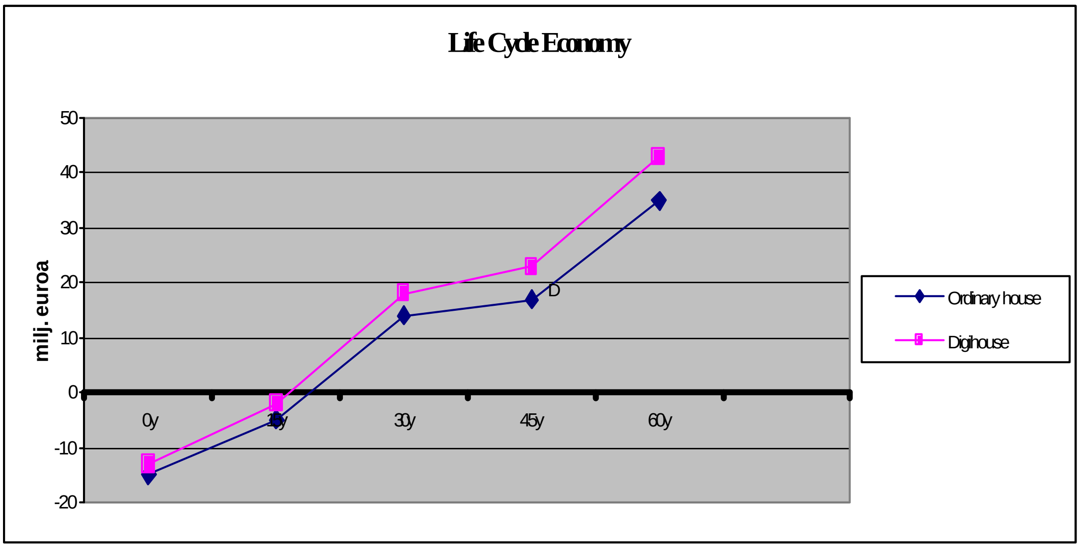
This was achieved by comparing various aspects of a traditionally designed and built office building with the solution which included many improvements (mainly upgrading the sustainability performance) in order to optimise LCC.

An additional objective was to assemble all essential building and economic information in one place, to calculate realistic lice cycle costs for rental (initial 15 years plus an additional 15 years) and to record the influence of the factors mostly affecting life-cycle costs (space-effectiveness, heating and electricity energy, inner climate and modification rate of these parameters).

LCC process

Objective	To compare two options – one built using traditional technologies and methods and the second utilising modifications for optimising the environmental performance and LCC. The analysis was required to produce not only figures for comparisons but also an assessment in aggregate of all relevant costs.
Preliminary identification of parameters and analysis requirements	The scope of the analysis involved the total asset including the pre-construction, design and construction, operation, maintenance and replacement. As the refinements and upgrades were made throughout the design the level of details was systemic/componential. The period of analysis was assumed to be 15 years for the LCC calculations however the depreciation period for the asset was considered to be 30 years. The methods of the economic evaluation were NPV and Payback (PB). The assessment of selected environmental indicators (to be finalised at later stages) will need to take place and accompany the LCC as stand-alone data. A separate environmental assessment was carried out by external experts and both options were assessed against the above criteria. No attempt was to be made to associate costs and results. Risk assessment was to include risk identification and basic sensitivity assessment of probable, optimistic and pessimistic values. The decision on the choice of sensitivity parameters could not be taken at this stage.
Confirmation of project and facility requirements	The facility's requirements were selected in order to optimised the Digi-house's performance regarding selected location, existing services in site, services the asset was expected to deliver (office accommodation, restaurant, parking, sheltered cycle stand, etc.), time of use, maintainability, recyclability, spatial solutions, energy economy , indoor conditions and flexibility for future modifications . The assessment of the following environmental indicators was decided upon: consumption of heating energy, consumption of facility energy and CO_2 emissions. One of the ultimate requirements was to select an HVAC system which was life-cycle optimised. Project requirements were focus ed on effectively supporting innovative work space design, energy savings and life-cycle economics.
Assembly of cost and performance data	All costs were itemised and costed using the Nordic classification. The model for maintenance was a follow - up, planned maintenance including technical and functional renewing. Values of financial parameters were identified as follows: discount rate of 3% (nominal), inflation rate 2%, and funding rate 35% over 15 years (real price of money). There is no data on the sensitivity analysis being carried out. General risk statement included risk identified as: advancement of resale-value, permanence of performance, maintainability and chances of valuation and compatibility of systems with further needs for facility management, mistakes concerning building planning, accessibility of building products, operative experience, risk of damage and way of use. In the production process risks identified were: insufficiency of professionals, problems with acquisitions, actions and transfer of project start towards winter time. In use and maintenance risks were: under-pricing in planning phase, defaults of use and maintenance directions, unexpected increases in prices, excessive and careless use of systems, unexpected damage and problems with usability in case of user changes and faults and lack of maintenance actions.
LCC analysis and results	All the financial parameters were applied uniformly to all costs. There were no tax advantages considered when selecting the design. All the values were input in the IT tools SeneCost for calculating the financial performance over the selected life cycle period.
Auxiliary analyses (risk and sensitivity) – optional	Critical risks were included in the risk register. There was no case identified for carrying out sensitivity analysis.
Interpretation and reporting	The main sections of the preliminary outputs from the software calculations were cash flow and profit estimates presented as tables and cumulated cost curve. The main sections and format of the final report presented to the client were as follows: object description, target and technical solution descriptions and some further explanations for the user. The final report could be easily adjusted to follow to the headings in ISO 15686 – Part 5.

Results



Results (continued)

The calculations enabled the client to foresee real cashflows and show the real economical meaning of life-cycle issues.

Based on the usefulness of the LCC calculations in Digi-house, similar calculations are carried out in each investment project (new buildings and renovations) of Senate Properties on 4 phases (preparation of project, planning, construction and use).

Contact details

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Conclusions and benefits

Life-cycle economical, energy economical, eco-efficient, healthy and social factors are quite similar: durable, energy-saving and desirable with functional, change-flexible and unrestricted spaces and reliable, advantageous, undamaged recyclable systems, other products and materials.

A real life-cycle optimisation is necessary in parallel to individual building planning.

Life-cycle optimised Digi-house meant:

- Reduction of heating and electricity energy making it easier to optimise energy management and increase importance of renewable energy resources.
- Increase of both GNP and employment and transferring labour inputs from energy producing countries to native countries and from wasting to recycling services.
- New kind of business possibilities (for example building concepts, coating structures, recycling products).

The update to the LCC analysis and calculations will be carried out after 3 years from the completion of the project.

4 Application of LCC methodology to a project for Maximilien Perret College for Region Ile-de-France in Alfortville, France

Project description

Project title – College for Higher Technical Education for Ministry of Education

Category – New college accommodation for public sector.

General project information – The client is Région Ile-de-France, which is the executive organisation acting as an owner of buildings used for educational purposes in Paris and its neighborhood.

The architecture for the college Maximilien Perret of Alfortville, was created between 1995 and 1997 by the Italian architect and town planner Massimiliano Fu ksas. The spaces allocated to different functions (teaching, technical, administrative, etc…) are organised around long curved footbridge and an atrium with views to the city.

The materials used, predominantly rough concrete, which returns to the industrial architecture are moderated by large windows and elements painted in vivid colours.

It is built on grounds of the vocational school created in 1887 to satisfy the requirements for skilled workers in construction. The college Maximilien Perret evolved/moved progressively with the industrial needs and the institutional changes. It comprises a general-purpose college with technological and professional sections.

Year of construction – 1997 (opened)

Gross internal floor area (GIFA) – 26,426 m^2

Aims and objectives of LCC analysis

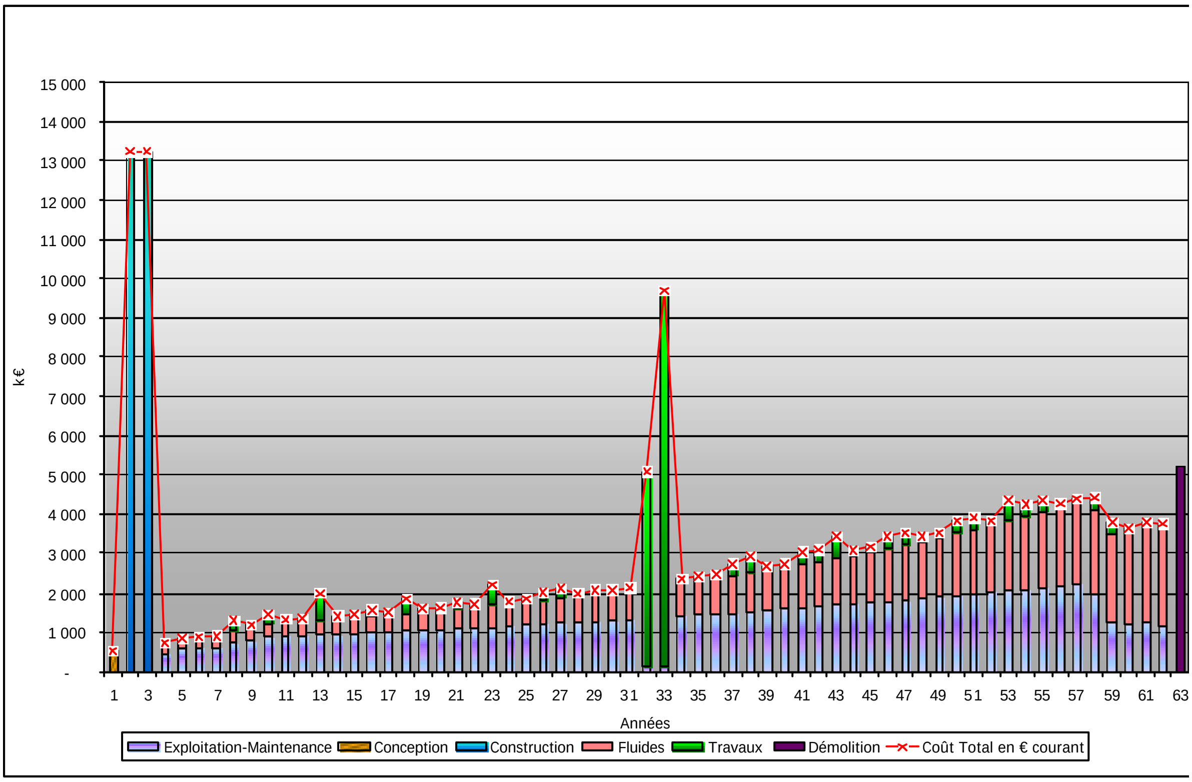
The LCC analysis for that building has been prepared in order to illustrate likely future expenditure required to build and exploit the building providing a variety of functions supporting adult education. The building's design was very modern and unconventional which provided another intangible parameter in LCC calculations.

The regional requirements of Local Authorities in the region Ile-de-France were the basis for undertaking the LCC exercise. Due to the prestigious and non-standard characteristics of the building, carrying out the LCC was considered in itself as a risk identification and mitigation experience.

LCC process

Objective	The main objective was to budget an option which was selected after extensive consultations between the design team and the client (Region Ile-de-France) as well as according to the architectural requirements resulting from unconventional design. Designers were brought on board to manage the LCC calculations and assessment. LCC also formed part of the decision for the procurement route and sustainable objectives. Maximilien Perret was the first French high school built with environmental standards.
Preliminary identification of parameters and analysis requirements	The scope of the analysis involved the total asset and all the stages of facility's life from costs of concept design which were not insignificant on this project (world famous architect) to demolition. The level of detail has eventually reached detailed design after many design iterations even during construction. The duration of the life cycle was assumed as 60 years and costs of demolition were included in 1997 calculations, although this did not mean that the building was designed and built to last 60 years only. 60 years is a standard period of analysis, but there isn't any specific justification for it. A calculation based over 10 years (2 for the construction and 8 for maintenance) was also carried out to define the budget of the construction company. The methods of the economic evaluation required by the client were NPV only. The Region's database contains also a basic assessment of the environmental performance for the majority of the entries, therefore at the design stage the environmental considerations were taken into account when making the selection decisions. However no separate sustainability assessment was decided upon. No separate risk or sensitivity analyses were envisaged.
Confirmation of project and facility requirements	Exceptional facilities (30 rooms equipped for specialized teaching - 11 workshops for design and assembly, 20 workshops of 250 m² each allowing the use of up-to date equipment in realistic situations, a multimedia room, a conference room, an information and documentation centre, a technical resources centre including information technology self service facilities, facilities for catering, etc.) were specified by the local authorities. The aspects such as quality, impact, aspect, access, etc. were high on the agenda and list of requirements was drafted to a high level of detail. Sustainability provisions were considered to be made when a selection of building components was decided upon. The decision to use low temperature heating by geothermics and double flow heat recovery provided the improved energy performance of the building. LCC calculations were carried out alongside LCA. Project requirements – there was no fixed budget but options were selected according to their prices during the design stages. The site constraints and project constraints were agreed and acted upon between the client and the design team (restricted site, adjacent buildings, architect's vision, etc.). The same applied to the quality requirements of the selected systems and components.
Assembly of cost and performance data	All costs were itemised using the French classification system UNTEC. The cost data was derived from quantity surveyor's internal databases which are linked to contractor's databases and other available published data. The main exercise was carried out for one option which has emerged from the design stages. Initially all areas were classified for their functionality (internal and external) and calculated. Various cost indices were then applied to different areas. Generally the costs were grouped for final calculations into costs relating to: cost of design, Capex, use & maintenance, labour and demolition. A separate spreadsheet referred then to the replacement regimes and to the maintenance frequencies. All relevant costs were applied accordingly. Values of financial parameters were assumed as follows: discount rate of 4% (real - as advised by French Ministry of Finance), 2% general inflation rate and 4% inflation rate applied to costs related to energy. Replacement timings for the assets were assessed using a combination of constructor's own database and published data on the likely life expectancy of various assets. Sensitivity analysis was not carried out as a separate exercise. An external risk register was produced by the design team; however it was not directly linked to the LCC process.
LCC analysis and results	All the financial parameters were applied uniformly to all cost groups, except for the inflation rate which was applied as 4% to all cost related to energy and 2% to all other costs. All the values were input in the IT tool (internally developed for CSTB).
Auxiliary analyses (risk and sensitivity) – optional	No separate quantitative risk analysis was carried out.
Interpretation and reporting	Results included the outputs from the Excel based LCC tool, providing the following information: tables of costs, parameters of the analysis, annual expenditure and detailed cost profile. The formal report to the client was structured according to French guidance but essentially it contained all the information which was easy to adjust to follow to the headings in ISO 15686 – Part 5.

Results from recent update to LCC with 1997 cost levels



Orange checked – Cost of design
Blue – Construction costs
Violet – Use & maintenance
Green – Replacement
Pink – Variable costs (geothermics, water and electricity)
Dark purple - Demolition

Results (continued)

The project is currently undergoing updates to the life cycle costing exercises because its initial maintenance contract is coming to an end. It is difficult to confirm the financial performance as cost data from the market place is not yet fully available and the up-to-date data will be commercially sensitive.
The main reasons for the LCC exercise were to justify environmental design and to define the procurement process. The high school was built under a global contract including construction and 8 years of maintenance.
A geothermic HVAC option was also selected.

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Conclusions and benefits

The main benefits were specifically connected to the building as a prestigious landmark for the region Ile-de-France:

- Cost monitoring during the construction and exploitation with aims to achieve further savings.
- Exploiting environmental HVAC options within a modern and controversial design solution
- Improvement of the indoor climate efficiency
- Special focus on maintenance and replacement costs throughout the exploitation phase due to potential obsolescence of some of the present options due to their innovative use and selection often without the support of the historical data on performance and costs.

5 Application of LCC methodology to a project for an office building for Ministry of Finance in the Netherlands

Project description

Project title – Office Building for Ministry of Finance

Category – New office accommodation for public sector.

General project information – The client is the Dutch Government Buildings Agency (GBA), which is the executive organisation for developing and operating real estate, and acting as the largest owner of buildings used by the Dutch national Government. The building is developed for the Ministry of Finance.
The building is intended to provide standard office accommodation of a medium to high quality. The facade has to be robust and the interior transparent in terms of the functionality, so it can be easily adjusted. The floor plans have to be suitable for a flexible office concept, with allocation of spaces allowing for open plan working, meetings, catering services, etc.

Year of construction - 2006-2008 (under development)

Gross internal floor area (GIFA) – 7,350 m^2

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Aims and objectives of LCC analysis

The main objective was to budget an option which was selected after extensive consultations between the design team and the client as well as according to the characteristics included in the category "medium to high quality" as specified within the departmental regulations and performance specifications.

The LCC analysis for that building has been prepared in order to illustrate likely future expenditure required to build and exploit the proposed office building. The analysis was also to be used to confirm the market prices for selected systems and components.

LCC process

Objective

The main objective was to budget an option which was selected after extensive consultations between the design team and the client as well as according to the characteristics included in the category "medium to high quality" as specified within the departmental regulations.

Preliminary identification of parameters and analysis requirements

The scope of the analysis involved the total asset and all the stages of facility's life from design to partial operation for 15 years. The level of detail has eventually reached detailed design after many design iterations.

The duration of operation was related to the clients' interest in the building as well as reliability of the results over a limited period of 15 years. After that period the ownership of the building will be transferred to a consortium. The methods of the economic evaluation required by the client were NPV only.

All the systems and components included in the GBA's database have a basic assessment of their environmental performance, therefore at the design stage the environmental considerations were taken into account when making the selection decisions.

There is a standard approach to risk management within the GBA's process. Selected risk categories with weighting factors are assembled in a database. The relevant categories are then selected and scored by the user group according to project's characteristics.

Confirmation of project and facility requirements

The facility's requirements were selected among the design team to optimise client's requirements for medium to high quality of office accommodation. All structural elements and services were selected including the external areas and parking lots by the building's ultimate owner. The occupier has then superimposed their additional requirements. In this case they related to furniture and preferred types of HVAC systems.

The risk categories relevant to the building were selected (among others, complexity and possibility of damage). The decision was made to further select and analyse these at later stages.

Project requirements: there was no fixed budget but options were selected according to their prices during the design stages. The site constraints and project constraints were agreed and acted upon between the client and the design team. Due to the presence of the rail line and tunnel as well as limited plot size certain design restrictions were imposed. The same applies to the quality requirements of the selected systems and components.

Assembly of cost and performance data

All costs were itemised and costed using the Dutch classification systems NEN 2634 and NEN 2748. The cost data was derived from GBA's internal databases, cost analyses and other available published data. The main exercise was carried out for one option which was selected throughout the design stages on "as you go" basis.

Values of financial parameters were assumed as follows: discount rate of 3% (real - as advised by Dutch Ministry of Finance), no inflation. However the risk-related discount factor was added to the nominal one and the total discount rate used was 7%. Because the risk factors are also in-built into the value of the discount rate, a more detailed and focused risk analysiswas encessary at this stage of the LCC process. This did not affect the integrity of the LCC process proposed in the methodology.

Replacement timings for the assets were assessed using a combination of GBA's own database and published historical information on the likely life expectancy of various assets.

Inclusions which were listed reflected certain costs associated with maintenance of the exterior and interior of the building, reinvestments on the interior of the building during the contract period, maintenance of the site, all catering activities, security of the property, cleaning of the interior and exterior, all furniture, FM costs

The main item listed in exclusions was ICT.

Sensitivity analysis was not carried out as a separate exercise. It was assumed to be part of the overall risk assessment. The risk categories were selected and their impact on the project and asset was assessed.

An external risk register was produced by the design team; however it was not directly linked to the LCC process.

LCC analysis and results

All the financial parameters were applied uniformly to all cost groups. However allowances for risk impact were made throughout the calculation through the significant adjustment of the discount rate.

All the values were input in the IT tool (internally developed for VROM), which iswidely available on the market and free to use on commercial projects as well.

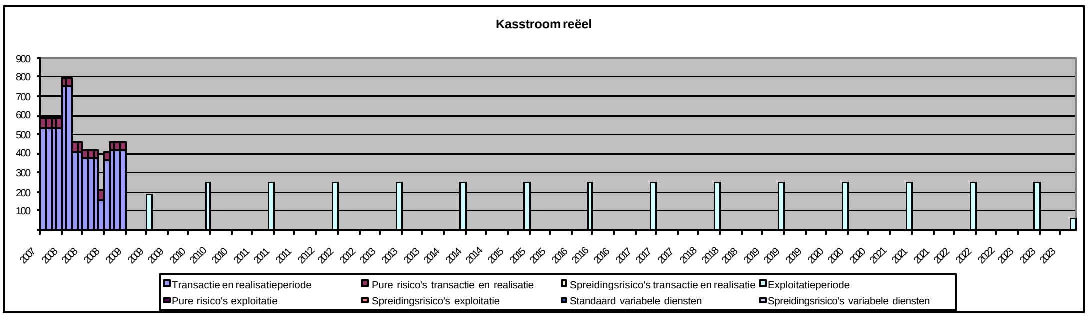
Auxiliary analyses (risk and sensitivity) – optional

The risk categories were selected and their impact on the project and asset was assessed. Some risks are included in the risk premium on top of the discount rate. These are the risks that are sensitive to the economic situation. Other risks are uncertainties in the cost calculations. These risks are included in the model as probability distributions. The last category of risks in the model includes the risks that are an extra cost item. They are priced by multiplying the chance of the occurrence of the risk and the consequences of that risk. The total of the last two categories is added to the total costs of the project.

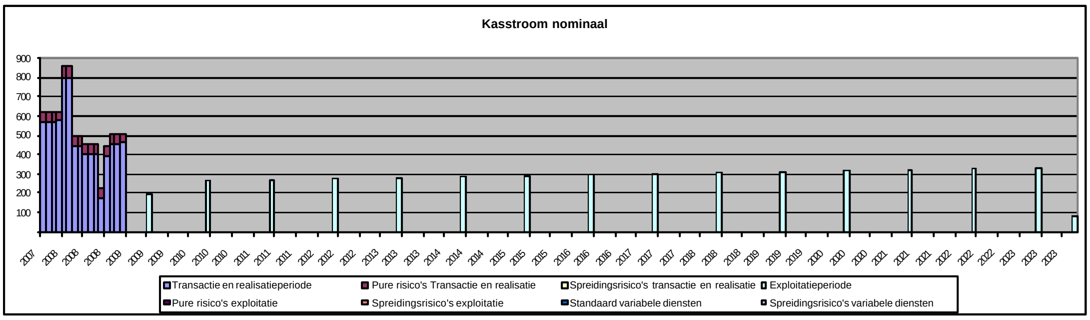
Interpretation and reporting

Results included the outputs from the Excel based LCC tool, providing the following information: tables of costs, parameters of the analysis, annual expenditure and detailed cost profile. The formal report to the client was structured according to GBA's guidance but essentially it contained all the information which was easy to adjust to follow to the headings in ISO 15686 – Part 5.

Results Real



Results Nominal



Blue – Capex; Violet – Cost of Risk; Green – Exploitation costs (annual)

Results (continued)

The project is currently undergoing further life cycle costing exercises at the detailed design stage and it is difficult to confirm the financial performance as cost data from the market place is not yet available.

Conclusions and benefits

The main benefits were in many ways typical for the LCC model utilised in the Netherlands:

- Itemisation of all costs and pricing using the Dutch standards and GBA's database of costs allowed to consistency of granularity with other projects
- Following the standard, well-refined cost assessment process for public procurement
- Access to government-supported databases of prices, costs and standard design solutions contributed to the optimisation of solutions.
- Access to benchmark data and reasonably accurate historical data reduced risks.
- Analysis of the results led to procurement using public/private cooperation.
- Using the standard model and GBA's software allowed for development of the consistent model and reliable outputs.

Future expected benefits are the synergies between the different disciplines (design, O&M).

6 Application of LCC methodology to a hospital building in Porsgrunn - - for Norway's Directorate of Public Construction - Statsbygg

Project description

Project title – Hospital Building in Porsgrunn for the client - Southern Norway Regional Health Authority the tenant -Telemark Hospital

Category – New psychiatric hospital wing for public sector

General project information – The name of the project is "DPS Porsgrunn" (DPS = district psychiatric hospital)

Architect: Ottar Architects
Consulting engineer: Ramboll Norway

A LCC calculation was carried out in the pre-project phase. The LCProfit model was chosen, and the aim was to get an overview of the total capital and MOMD (management, operation, maintenance and developmet) cost of the project. The results was compared to best practice and benchmarked against the existing regulations.

Year of construction - 2006-2007 (under development), with completion date Aug. 2007

Gross internal floor area (GIFA) – 4,846 m^2

Heated gross internal floor area (GIFA) – 4,496 m^2

Contact details
Rambøll Norway – Mr. Sven Egil Nørsett
E-mail: sven.norsett@ramboll.no

Aims and objectives of LCC analysis

The aim of the calculation was to obtai an estimate of the total LCC (capital + MOMD) at an early project stage (pre-detail phase). The MOMD costs were then benchmarked against best practice.

In 1998, Statsbygg, Norway's Directorate of Public Construction and Property, instituted a requirement for annual cost calculations for all projects in the pre-design phase. This means that project designers are contractually obliged to submit annual cost calculations along with the other pre-project materials. Later this practice was implemented in the law on public procurement.

The input data was taken from budget estimates at the pre- detail phase, i.e. the calculations were done on a "coarse" costing level. Other assumptions for the calculation were taken from the MOMD-database "Holte FDV" (from "Holte Byggsafe") and from Ramboll Norway's own experience and data on LCC-calculations.

The LCProfit model does not handle "likely", "best" and "worst" case scenarios well (one set of assumptions has to be used for each case). The calculations in the case study are done based on "likely" values.

LCC process

Objective	The main objective was to budget an option which was developed at the pre-detail design stage. This initial budgeting exercise was subject to verification at later stages as to whether the rent will cover the actual annual costs, or whether the Directorate is likely to make a profit or loss on the project. Selected choices regarding the structure and M&E system were made based on experience and past cost data for similar projects throughout the preliminary design stages.
Preliminary identification of parameters and analysis requirements	The scope of the analysis involved the total asset and all the stages of facility's life (no disposal costs). The appraisl period was set to 40 year as instructed by the project owner. The recommended appraisal period of a new build was 60 years (public buildings). This has to be taken into account when comparing to best practise (benchmarking). Calculations for an appraisal peroid of 60 years was also done for comparison. The methods of the economic evaluation required by the client were NPV only and this is the main calculation method in the software LCProfit which supports the NS 3454 – Annual Costs for Buildings. "Holte Byggsafe" which publish the "Holte FDV" database, is a well established firm in Norway that developes calculation tools for the building industry as well as databases with building and cost data. FDVU is the Norwegian acronym for MOMD (management, operational, maintenance and development). Their product/cost databases do not contain the environmantal performance data (LCA), therefore the environmental considerations w ere reduced to benchmarking the energy use against best practise and the new requirement on energy use in buildings (as of 01.01.2007).
Confirmation of project and facility requirements	The facility's requirements were selected among the design team to optimise client's requirements for the hospital building with the purpose of holding a psychiatric ward with capacity for 75 patients (of which a capacity of 15 patients on day -and-night care, and the rest poly-clinical). As this was an additional building to an existing hospital complex the asset's requirements had to take into account fitting into the existing complex not only architecturally but als o from services perspective. All structural elements and services were confirmed, including the external areas and parking lots, by the building's tenant. The choice of HVAC systems was a trade-off between current environmental performance, cost and possibility of future replacements with a more efficient system. The energy use was also compared to existing statistics and the requirements in the revised law on energy use in buildings as a result of the new EU directive on energy use in buildings. It was suggested to the client that a more thorough energy calculation should be carried out, as well as a second LCC analysis with a building solution with better/more insulation, low energy lighting system and focus on building details. Project requirements – there was a fixed budget of 107.8 million NOK and the options were selected according to their prices during the design stages. The site constraints and project constraints were agreed and acted upon between the client and the design team. The quality and performance requirements had to correspond to Norwegian standards for hospitals.
Assembly of cost and performance data	Annual costs were calculated according to NS 3454. The capital cost was expected to be higher than best practise. The MOMD-cost may be higher/lower depending on the chosen solutions. Capital costs (investment costs) are only part of the annual costs associated with owning, operating and maintaining a building. MOM costs comprise 35-50% of the total annual costs of Statsbygg's buildings, meaning they have a significant impact on rents. The discount rate was selected according to the recommendation from the "Norwegian government calculation committee" (simular to the Treasury Green Book) and set as 6% (to be confirmed whether real or nominal). Replacement timings for the assets were assessed using a combination of Ramboll's own database and the "Holte FDV" database. The residual value was not taken into account, as this has not been practised in public projects so far. An external risk register was produced by the design team; however it was not directly linked to the LCC process.
LCC analysis and results	All the financial parameters were applied uniformly to all cost groups. LCProfit was used as calculating tool. The results were presented to the owner in a report in accordance with NS 3454 with recommendations for further analysis and conclusions.
Auxiliary analyses (risk and sensit-ivity) – optional	There are no calculation capabilities within LCProfit for risk or sensitivity analyses and the client has not requested a separate one.
Interpretation and reporting	Results included the outputs from the LCProfit, providing the following information: tables of costs, parameters of the analysis, annual expenditure and detailed cost profile. The formal report to the client was structured according to LCProfit's outputs and guidance from NS 3454 but essentially it contained all the information which was easy to adjust to follow to the headings in ISO 15686 – Part 5.

LCC results (main figures)

Version 4.0.1

Life cycle cost calculation

All results are calculated incl. value added tax.

Project fase:	**Forprosjekt**
Calculation mode:	**Detaljberegning**
Calculation no.:	**1**

6050806 DPS Porsgrunn

Nybygg **Porsgrunn**

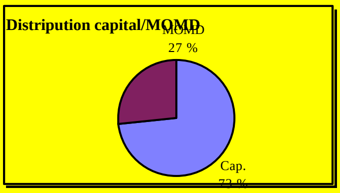
Information and assumptions

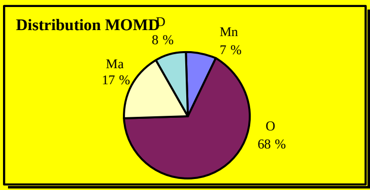
Tenant	Helse Sør	Calc.rate of return	6,0 %
Use of premises	Psykiatri (poliklinisk og døgnpost)	Baseline NOK date	1. jan. 2006
Number of "people"	75	Functional lifetime	40 år
Gross area	4 846 m2	Cost of project	107,8 mill.kr
Value building		Budget limit	107,8 mill.kr
Area of parks/lawn		Value site	
Area of roads/parking			

Illustration

Annual costs — *Annual cost with baseline NOK value* 1. jan. 2006

	Landlord's resp. and cost	*Tenant's and cost*	*L.lrd's resp. - tenant's cost*	*Total annual cost*
10 Capital cost	7 386 233 kr 1 524 kr/m2			7 386 233 kr 1 524 kr/m2
20 Management cost	199 296 kr 41 kr/m2			199 296 kr 41 kr/m2
30 Operating cost		1 434 177 kr 296 kr/m2	372 866 kr 77 kr/m2	1 807 042 kr 373 kr/m2
40 Maintenance cost	299 808 kr 62 kr/m2	9 238 kr 2 kr/m2	157 447 kr 32 kr/m2	466 494 kr 96 kr/m2
50 Developement	138 306 kr 29 kr/m2		79 754 kr 16 kr/m2	218 060 kr 45 kr/m2
60 (Unused) (Not implemented)				
70 Service and support				
80 Potential (Not implemented)				
90 (Unused) (Not implemented)				
Sum annual costs	8 023 644 kr	1 443 415 kr	610 067 kr	10 077 126 kr
per square metre	1 656 kr/m2	298 kr/m2	126 kr/m2	2 079 kr/m2
per unit (employee, patient)	106 982 kr	19 246 kr	8 134 kr	134 362 kr

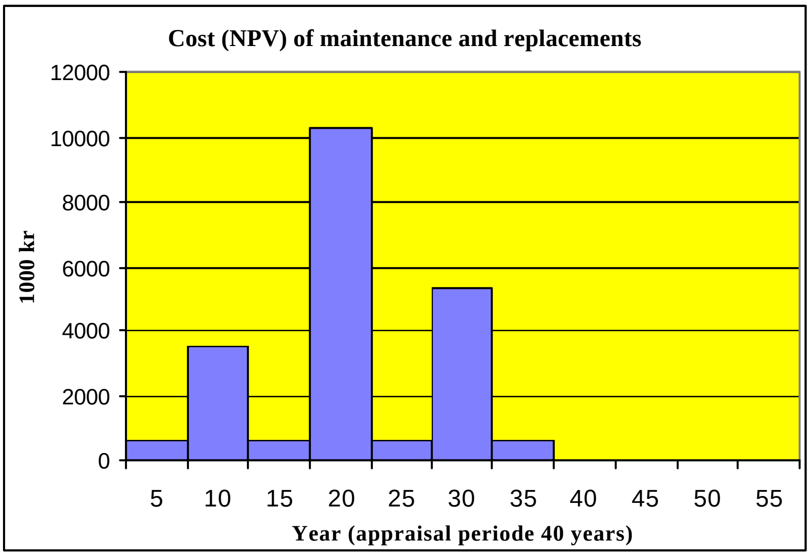




Calculated by

Sven Egil Nørsett	Rambøll Norge AS	13.01.2006

Cost (NVP) maintenance and replacements



Results (continued)

The results constituted an overview of individual cost components' contributions to annual costs, and their apportionment with regard to responsibility and cost. This apportionment is in accordance with Statsbygg's standard lease.

A similar overview, calculated on a square metre basis, accompanies the first results. Further on there are sheets showing the detailed calculation.

Management costs include property tax, water and sewer fees, refuse collection and disposal, insurance and administration. Energy use and cost is a main focus. Energy for heating (building, ventilation and hot water) is supplied by district heating. Electricity is assumed for all other purposes. The energy price was based on existing contracts (in accordance with the owner). These prices were quite low, and a sensitivity analysis was recommended for further work.

Conclusions and benefits

The main conclusion from the LCC analysis recommended a stronger focus on energy use. The architectural and technical design at the pre-project phase would give higher energy use than best practise and in comparison to the new regulations on energy use in buildings.

Due to costs and progress of the project, the conclusions of the analysis was only partly taken into action.

7 Application of LCC methodology to Museum of World Culture in Gothenburg in Sweden

Project description

Project title – Museum of World Culture in Gothenburg, Sweden

Category – Museum building for public sector – National Property Board.

General project information – The design by architects Cecile Brisac and Edgar Gonzalez gives the Museum of World Culture a robust frame for its activities. The building has already been awarded Sweden's Kasper Salin Prize for architecture. The cement and glass building, located on a slope, is graceful, compact and modernistic. Its four-storey glass atrium looks out on mountains and woods. The exhibition halls are in the closed part of the building. The upper storeys hang five metres over a footpath. A 43-metre long section of a display window provides passers-by with a view straight into the largest exhibition hall.

The National Property Board's Role has been to manage the entire project, ensure that all of the museum's requirements have been fulfilled and to steer the project within the economic framework allocated by the government.

Exhibition area: 2,600 m^2, six storeys, five exhibition halls, research library and offices. Cost: SEK 305 million

Year of construction – 2001-2004 (opened 29th December)

Gross internal floor area (GIFA) – 11,000 m^2

Aims and objectives of LCC analysis

The main objective was to support the design of the prestigious landmark structure (museum) with continuous LCC calculations of selected systems based on the combination of cost and their environmental performance. The most important of the studied systems and some of the building structures (insulation, windows) were analysed with LCC during the design stage.

Energy efficient procurement principles based on the ENEU® concept (Energy Efficient Procurement) were applied with LCC and also introduced as part of the purchasing routines.

Investments with long pay-off time were made profitable when calculating with ENEU® concept and LCC. On the museum project HVAC systems cooling and heat pump systems as well as circulation pumps were procured using the ENEU® concept, which was developed by Bengt Dahlgren AB in 1994 and today it works almost as a standard in Sweden and also in other Scandinavian countries.

Consultants have carried out environmental reviews throughout the project, in order to guarantee that the established environmental demands have been followed. The environmental demands on the project included requirements for environmental and health reviews of material, environmentally educated personnel, waste and materials management, and handling of chemicals. The use of energy is one of the most important things in these analyses.

LCC process

Objective

The main objective was to follow the principles of the winning design by prestigious architects and at the same time allowing for design and selection of systems which would provide optimal environmental performance. Options which were selected during the design stage were put together based on LCC assessment and LCA.

Preliminary identification of parameters and analysis requirements

The scope of the analysis involved assessing LCC for selected systems identified based on their environmental performance. Carrying out the LCC for the whole constructed asset is not a common practice in Sweden. The costs of disposal of the selected systems and potential income from recycling were not included. The assessments and decision selection took place throughout the design phase.

All LCC for the systems were calculated based on the NPV method of economic evaluation. The financial parameters considered were real interest rate above inflation and the duration of selected stages of life cycle – as 20-30 years depending on the data on the system.

The systems subjected to LCC were heating, cooling, ventilation, insulation, etc. namely all systems responsible for the energy use and for the indoor climate. The protection of the exhibits was a significant factor in the selection.

Because the environment was a strong decision criterion during the architect competition, the cubic shape of the building was chosen as it leads to a lesser energy consumption than of e.g. loaf shaped building. All the built-in materials had to be reviewed from an environmental and health aspect. Building declarations had to be provided for all the materials used. The intention was that museum had to be completely free of PVC.

Risk analysis was carried out separately from LCC and focused on quality of air, fire protection, energy price, using ammonia in the cooling systems etc.

Sensitivity analysis was carried out for the prices of energy and for the increase of the energy prices for electricity and for district heating.

Confirmation of project and facility requirements

The facility's requirements were selected among the design team to optimise client's functional and environmental requirements. All structural elements and services were selected including the external areas based on a combination of architects' design and environmental performance.

All the built-in materials have been reviewed from an environmental and health aspect. Building declarations have been provided for all the materials used.

Project requirements – there was a fixed total budget from the Swedish Government, but options were selected according to the optimal balance between the cost and environmental performance. The site constraints and project constraints were agreed and acted upon between the client and the design team. The quality requirements of the selected systems and components were also an important factor.

Assembly of cost and performance data

All costs were itemised using an expert on cost calculations of buildings and installation systems within the design team.

Costing of the items of preferred environmental performance and LCC analysis, resulted in e.g. selection of a heat pump, with ten rock (bore) holes, 185 meters down into the rock, which partly heats the museum in the wintertime and cools the museum during the summertime.

Values of financial parameters were assumed as follows: real interest rate (above inflation) of 6.5%, an yearly real increase of the price for electricity 1.5% , for the district heating with 1.3% and for the maintenance 0.5% (as agreed between the client which was National Property Board and by the LCC practitioners) and depending on the system they were applied to – local solar cells for electricity production, heating and cooling systems, the size of the HVAC-units, the thickness of the thermal insulation etc.

Sensitivity analysis was not carried out as a separate exercise. It was assumed to be part of the overall risk assessment. The risk categories were selected and their impact on the project and asset was assessed.

The energy use was calculated by using an advanced simulation tool, which also take into account the interaction between the building structure and the HVAC-systems and the internal loads as heat gains from the sun, people and from different machinery.

LCC analysis and results

The financial parameters were not applied uniformly to the cost groups. The duration of the life cycle varied from 5 to 30 years (insulation). Mostly it was 20 – 25 years. See details in the previous section.

All the values were input in the IT tool, which is internally developed for the purpose of the company.

Auxiliary analyses (risk and sensitivity) – optional

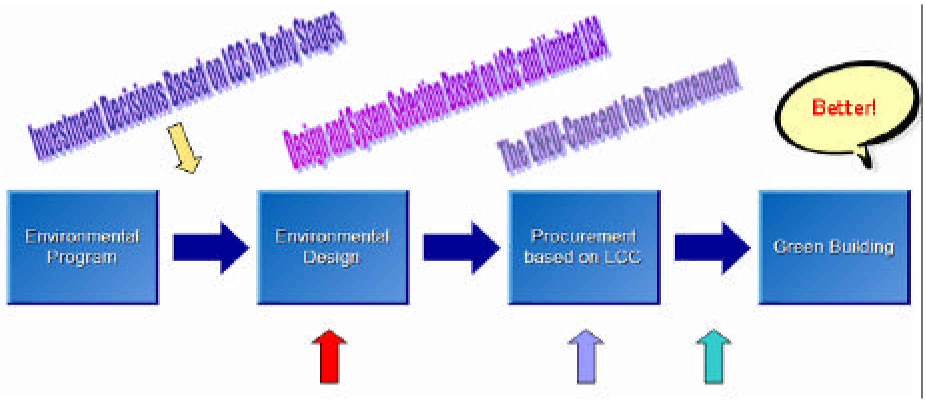
Risk analysis was carried out by the specialist engineers. An external risk register was produced by the design team; however it was not directly linked to the LCC process.

The sensitivity analysis was carried out for different values of the interest rate and the increase of the energy price.

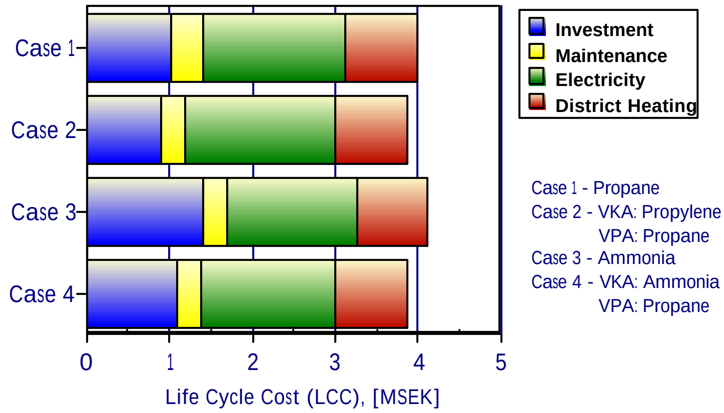
Interpretation and reporting

Results included the outputs from the Excel based LCC tool, providing the following information: tables of costs, parameters of the analysis, annual expenditure and detailed cost profile. The formal report to the client was structured according to Swedish standards but essentially it contained all the information which was easy to adjust to follow to the headings in ISO 15686 – Part 5.

Model for use for LCC Analysis in the Design Process used in the project.



Results Analysis of Cooling Systems



Results (continued)

The impact of the ENEU® concept and LCC analysis of selected systems had a significant influence on the overall design of the museum building. Combining information from systems environmental assessment, the demands from the users of the building and the overall LCC performance generated an optimal solution.

Conclusions and benefits

The main benefits were in many ways typical for the LCC model utilised in Sweden:

- All the built-in materials have been reviewed from an environmental and health aspect. Building declarations have been provided for all the materials used.
- The museum is almost completely free of PVC
- There has been a big focus on the indoor environment, with the intention of 'P-marking' the museum - this is a rating given to a building that meets specified standards for the indoor environment. These demands include thermal comfort, air quality, damp, radon, light, noise, as well as electrical and magnetic fields. It is also required that there are established routines for indoor environment controls.

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